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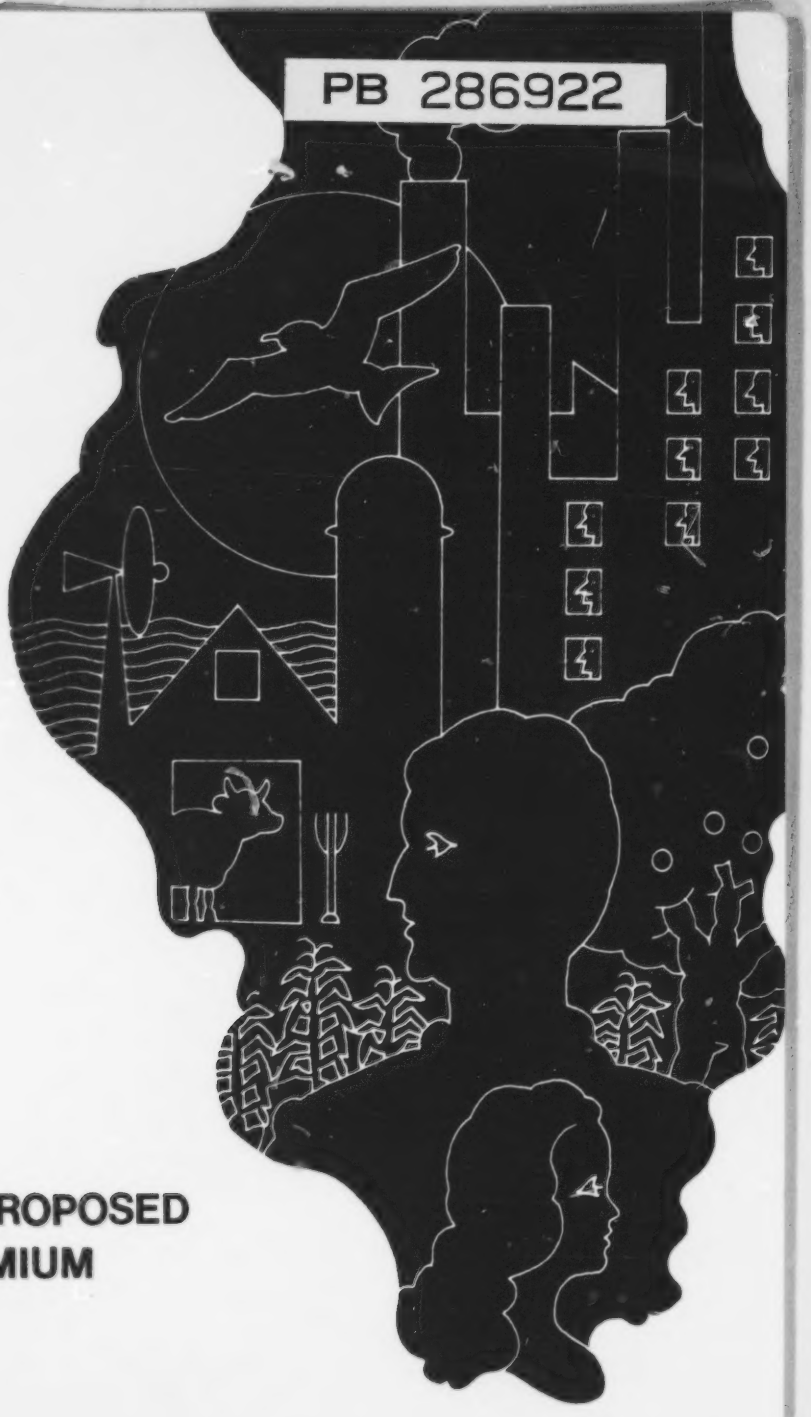

ECONOMIC IMPACT OF PROPOSED AMENDMENTS TO CHROMIUM EFFLUENT STANDARDS IN ILLINOIS (R76-21)

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As a result of a review by the Illinois Effluent Standards Advisory Group (IESAG) of the Illinois water pollution regulations, several modifications of pollutant levels were recommended. As part of R76-21, the effluent levels of hexavalent, trivalent, and total chromium were proposed. The basis of the proposed change is the presumption that the standard can be attained by using "good conventional technology at no significant incremental increase in treatment costs."

The change in the chromium effluent standard will result in more stringent levels of control which whould reduce the quantity of chromium discharged to the environment.

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by

Linda L. Huff

Project No. 80.103

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State of Illinois
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Frank Beal, Director

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NOTE

This report has been reviewed by the Institute for Environmental Quality and approved for publication. With the exception of the Opinion of the Institute's Economic Technical Advisory Committee, views expressed are those of the contractor and do not necessarily reflect the position of the IIEQ.

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Opinion of the Economic Technical Advisory Committee
of the Illinois Institute for Environmental Quality

The Economic Technical Advisory Committee has reviewed the Economic Impact Study, IIEQ Document No. 77/08, entitled Economic Impact of Proposed Amendments to Chromium Effluent Standards in Illinois (R76-21). The Committee finds the report to be generally responsive to the requirements of Section 6 of the Environmental Protection Act, and recommends that it be forwarded to the Pollution Control Board so that public economic impact hearings may be held in connection with the proposed regulatory action: R76-21, Amendments to the Water Pollution Regulations of the Illinois Pollution Control Board.

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EXECUTIVE SUMMARY

Regulatory proposal R76-21, which consists of general revisions to the effluent regulations of Chapter 3, Water Pollution Regulations, includes a modification of the present chromium standards. The Illinois Effluent Standards Advisory Group (IESAG) recommended a more restrictive limitation for hexavalent chromium because of the effluent quality attainable through existing chromium treatment technology. The present standard of 0.3 mg/ℓ hexavalent chromium as a daily maximum is to be replaced by a 0.1 mg/ℓ monthly average with 0.2 mg/ℓ daily maximum for hexavalent chromium. The existing trivalent chromium concentration of 1.0 mg/ℓ daily maximum is revised to total chromium of 1.0 mg/ℓ as a monthly average and 2.0 mg/ℓ as a daily maximum. In addition to this proposed effluent limitation, an effluent standard for hexavalent chromium of 0.15 mg/ℓ monthly average and 0.3 mg/ℓ as a daily maximum was investigated. These two alternatives provided an indication of the economic and environmental tradeoffs associated with more restrictive levels of regulation.

Cost and Benefits

The IESAG proposed regulation will directly impact seven dischargers* and their associated receiving streams in Illinois. The environmental consequences are based upon the uses and characteristics of these seven streams. The predicted reduction in chromium loading to streams will be approximately 8.7 pounds per day over seven streams. The maximum change in stream concentration ranges from 0.0003 mg/ℓ to 0.1 mg/ℓ as shown in

*Four other dischargers currently violate both the existing and proposed standards; however, no incremental costs or benefits were assigned. See Chapter 4.

Table 1. The major environmental benefits accrue to users and aquatic biota in Cone Creek and Aux Sable Creek. These benefits consist of protection of Aux Sable Creek as a future water supply and greater protection for fish, invertebrates, algae, and other biota within the two small, intermittent streams identified. There is some uncertainty regarding the fate of chromium in the environment in terms of sediment accumulation and synergistic effects, and a lower standard would reduce this element of risk. These expected environmental benefits are very site specific because of the limited number of affected dischargers. Although general use water quality violations of the chromium standard do occur at 12 of the 576 stations, there appears to be a correlation between point sources and water quality for only three stations. Possible explanations for this include natural phenomenon, analytical error, or the point source discharge of chromium which is not regulated.

To provide higher levels of protection requires the expenditure of additional funds by the impacted dischargers. Of the 54 sources in the state who discharge some level of chromium in their effluent, 7 are directly affected by the proposed regulation. Although five of these impacted firms have chromium treatment facilities, they will be unable to comply with the proposed regulation unless additional operating expenses are incurred. Two other dischargers would be required to add major treatment facilities. The total increase in annual operating costs would be $4,500,000 and the capital expenditure could be as much as $5,400,000 if the proposed regulation is adopted.

Table 2 illustrates the anticipated costs and benefits of the proposed

X

Table 1

RECEIVING STREAM CHARACTERISTICS

Receiving Stream	7-day, 10-year Low Flow, mgd	Maximum Hexavalent Chromium Level,[1] mg/ℓ
Cone Creek	0	0.23
Rock River	691	0.0003
Big Creek	0	No change
Nippersink Creek	1.3	0.0009
Pecatonica River	143	0.002
Illinois River	2093	0.00003
Aux Sable Creek	0	0.22
Illinois River	1937	0.003

[1]Calculated based on low flow conditions and average chromium loadings at the existing standard.

Table 2

TOTAL SOCIAL BENEFITS AND COSTS

Regulatory Scenario	Total Social Costs	Total Social Benefits
I. Existing effluent standard	Existing costs	Existing water quality
II. Proposed regulation, R76-21 0.1 mg/ℓ, monthly average Cr^{+6} 0.2 mg/ℓ, daily maximum Cr^{+6} 1.0 mg/ℓ, monthly average Cr (total) 2.0 mg/ℓ, daily maximum Cr (total)	A. Additional operating costs of $4,500,000 per year.[1] B. Capital expenditures of $5,400,000 C. Increased discharge to two streams of biocides and nutrients replacing chromates in cooling system.	A. Protection of Aux Sable Creek as future water supply source.[24] B. Greater protection of aquatic biota in Aux Sable Creek and Cone Creek, especially invertebrates and algae. C. Reduced accumulation of chromium by 56% over existing conditions. D. Hexavalent chromium loading reduced by 8.7 pounds per day.
III. Alternate regulation 0.15 mg/ℓ, monthly average Cr^{+6} 0.30 mg/ℓ, daily maximum Cr^{+6} 1.0 mg/ℓ, monthly average Cr (total) 2.0 mg/ℓ, daily maximum Cr (total)	A. Additional operating costs of $170,000[1] B. Capital expenditure of $1,000,000 C. Increased discharge to one stream of biocides and nutrients replacing chromates in cooling systems.	A. Protection of Aux Sable Creek as future water supply. B. Greater protection of aquatic biota in Aux Sable Creek and Cone Creek, especially invertebrates and algae. C. Chromium accumulation in sediment reduced by 34% over existing conditions. D. Hexavalent chromium loading reduced by 5.3 pounds per day.

[1] Includes annualized capital costs.

regulation and an alternative regulation which allows a higher monthly average and daily maximum hexavalent chromium standards.

The incremental change in costs between the proposed and the alternative regulation is attributed to the decrease in affected dischargers. As the number of dischargers potentially impacted decreases from 7 to 5, the capital cost incurred is reduced to $1,000,000 (one discharger's investment) and the operating expense to $ 170,000 (five discharger's annual expense). The alternative standard eliminated the variability in cost estimating by improving the acceptability of two effluents.

With the alternative effluent regulation there would be a 5.3 pound per day decrease in hexavalent chromium rather than 8.7 pounds per day reduction associated with the proposed regulation. This incremental change of 3.4 pounds per day or 1240 pounds per year would reduce capital investment by a maximum of $4,400,000 and operating expenses by $4,300,000. The accumulation of chromium in the stream sediment would be reduced by 56% or 34% over existing conditions for the proposed and alternative regulation, respectively.*

The costs are reduced as the number of impacted dischargers decreases to five; however, the magnitude of environmental benefits is not greatly changed. Thus, both regulations offer an improvement in water quality; however, the incurred costs for the two levels of regulation vary substantially. The uncertainty in the level of environmental protection provided is decreased with a more stringent standard, and this change represents a qualitative consideration of the change in effluent standard.

*This reduction pertains only to the seven river basins affected by the proposed regulation.

Economic Impact

The economic impact incurred is based upon the magnitude of the compliance costs and the economic characteristics of the affected discharger. Table 3 presents the incremental operating and capital costs incurred for each discharger. No costs are associated with compliance for four of the dischargers, and the remaining dischargers incur costs at two alternative levels of regulation. D, I, and K will require additional treatment facilities, although only two establishments, I and K, will be faced with significant capital investment. Such expenditures could not cause plant closure but would curtail future expansion plans and could affect the plant profitability.

No change in industrial output or prices, commercial output or prices, and agricultural output or prices is anticipated. Local services and taxes will remain unchanged.

Concluding Remarks

The consideration of the proposed effluent standard requires analysis of potential water quality impacts and the imposed costs of treatment. These two important factors should determine the average and maximum level of effluent quality which is economically reasonable. Because of the uncertain fate of chromium in the environment and its effect upon the aquatic food chain, it is important to consider present water quality conditions. Twelve of 576 water quality stations exceeded the general use water quality criterion for hexavalent chromium, and of these only three were associated with point source discharges (IEPA data showed these

Table 3*

SUMMARY OF OPERATING AND CAPITAL COSTS INCURRED FOR ALTERNATIVE EFFLUENT REGULATIONS

Discharger	Increased Operating Costs,[1] ($/year)		Capital Costs, ($)	
	Proposed Regulation	Alternative Regulation	Proposed Regulation	Alternative Regulation
A	4,500	4,500	0	0
B	1,300	1,300	0	0
C	0	0	0	0
D	900	0	$5,000-10,000	0
E	3,200	3,200	0	0
F	No costs assigned		No costs assigned	
G	No costs assigned		No costs assigned	
H	No costs assigned		No costs assigned	
I	160,000	160,000	1,000,000	1,000,000
J	1,300	1,300	0*	0
K	4,300,000	0	4,400,000	0
Total	4,500,000	170,000	5,400,000	1,000,000

*Incremental increase in operating and capital cost resulting from the adoption of the proposed chromium effluent standard (compared to the existing standard).

[1]Amortized capital costs were included for dischargers I and K in the operating cost estimation.

dischargers to be in compliance with the existing regulation). There is concern not only with water quality but also with the accumulation of chromium in the sediments of rivers. According to Mr. Sparks of the Natural History Survey,*

> The chromium discharged in small streams may accumulate far downstream in the sediments of the larger rivers . . . chromium levels in clams and worms which lived in bottom sediments approached the chromium levels of the sediments themselves, whereas fishes contained much less chromium, and the water contained the least. . . . There would be downstream benefits as well.

Illinois has water quality standards for general stream protection; however, effluent regulations provide assurance that water quality will be maintained. In assessing the costs which are incurred for achieving a better level of protection, the most important concern is not the proposed establishment of a monthly average standard at 0.10 mg/ℓ of hexavalent chromium but the allowed variability in effluent quality. The U.S. Environmental Protection Agency has recommended in pretreatment guidelines for electroplating facilities a daily maximum hexavalent chromium level 2.8 times the monthly average standard (which has been set at 0.09 mg/ℓ Cr^{+6}). The maximum daily variability in effluent quality of the impacted dischargers exceeds the 2.0 times the monthly standard by the IESAG committee. For a standard of 0.15 mg/ℓ hexavalent chromium as a monthly average with a maximum of 0.3 mg/ℓ, the incurred capital cost is reduced from an estimated $5,400,000 to $1,000,000 and the operating cost is reduced from $4,500,000 to $170,000. Even if the

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*Mr. Richard Sparks letter to the Institute for Environmental Quality, May 10, 1978.

0.10 mg/ℓ hexavalent chromium monthly average is adopted with a maximum of 0.30 mg/ℓ, there would be a reduction in costs for two dischargers.

The environmental impact of these incremental changes are summarized in Table 2 for the specific streams and overall loading for accumulation in stream sediment. The costs incurred are associated with only a small group of dischargers; however, the environmental consequences of providing some additional economic relief by adopting an alternative standard of 0.15 mg/ℓ-0.3 mg/ℓ hexavalent chromium and the proposed 1.0/2.0 total chromium standard indicates that such an alternative regulation deserves consideration.

Chapter 1

INTRODUCTION

As a result of a review by the Illinois Effluent Standards Advisory Group (IESAG) of the Illinois water pollution regulations, several modifications of pollutant levels were recommended. As part of R76-21, the effluent levels of hexavalent, trivalent, and total chromium were proposed at the following concentrations:

Parameter	Present Allowed Concentration, mg/ℓ	Proposed Concentration, mg/ℓ
Chromium, hexavalent	0.3, daily maximum	0.1, monthly average 0.2, daily maximum
Chromium, trivalent	1.0, daily maximum	-
Chromium, total	-	1.0, monthly average 2.0, daily maximum

The basis of the proposed change is the presumption that the standard can be attained by using "good conventional technology at no significant incremental increase in treatment costs."

The change in the chromium effluent standard will result in more stringent levels of control which should reduce the quantity of chromium discharged to the environment. Thus, water quality will be improved, and, as a result, water users affected by chromium will benefit from the regulatory change. Benefits may accrue in the following areas: domestic water supply, agriculture, and fishing (via aquatic biota effects). In Chapters 2 and 3 the environmental consequences and benefits are described in detail.

Costs associated with the proposed regulatory change are primarily costs for chromium removal or an increase in operating costs associated with the elimination of chromates in cooling tower applications. Dischargers affected, such as electroplating establishments, and industrial users of chromates for corrosion control, are delineated in Chapter 4.

The regulatory scenarios considered consist of the following:

1. the existing standard
2. that proposed by the IESAG Committee
3. maximum allowable hexavalent chromium levels of 0.3 mg/ℓ daily maximum, and 0.15 mg/ℓ monthly average.

In evaluating the costs and benefits of regulation, all three of these scenarios are considered.

Chapter 2

CURRENT AND ANTICIPATED ENVIRONMENTAL CONSEQUENCES

2.1 Introduction

The recommended reduction in the hexavalent and total chromium effluent standard is based on improvements in treatment technology control. The consequence of a more stringent effluent standard is important in assessing the overall benefits of the proposed regulatory change. By describing the present water quality status and the anticipated improvements in water quality, the magnitude of environmental change can be placed in perspective.

In the following section the toxicity of chromium to water users is described. Then, the present concentration of chromium in receiving streams is summarized according to data collected by the Illinois Environmental Protection Agency (IEPA). Existing water quality violations are aggregated by river basin to emphasize the possibility of combined discharger effects. After the industrial discharges containing chromium have been identified, then the expected change in chromium loading associated with the standard change is projected. This result provides a basis for the description of anticipated environmental consequences.

2.2 Chromium Toxicity Data

Chromium is an element which is present in the air, soil, food, and water of our environment. The trivalent form is predominant in nature although many oxidation states do occur from Cr^{-2} to Cr^{+6}. The

toxic levels of chromium to human health, fish, irrigation, and livestock are presented herein as a basis for reviewing the present water quality within Illinois.

2.2.1 Human Health

Chromium is an essential trace element and occurs in most biologic material in the trivalent form, in which it is strongly associated with proteins and nucleic acids.[19] Exposures in the environment through the air and water provide a significant quantity of the hexavalent form taken in the body. The health impact of chromium ingested via water is uncertain because of the lack of sufficient data. Specific studies are cited herein to indicate the available knowledge.

Hexavalent chromium in the air is irritating and corrosive to the mucous membranes. Knowledge of the harmful effects has been obtained from occupational health studies. Lung cancer, ulceration and perforation of the nasal system have been observed in workers inhaling hexavalent chromium.[21]

Excessive intake of chromium in man has only recently been studied. There is a reported case of a family which used chromium-contaminated well water for a period of three years without any deleterious effect to their health as determined by a single medical examination.[7] McKee and Wolf (1963) reported no serious effects from a human volunteer who for fifteen days drank water which contained 10 mg/ℓ of Cr^{+6}. It was reported, however, that nausea occurred at three different periods during the experiment.[18]

Chronic toxicity of chromium has been observed in rats when drinking

water contained concentrations of 5 mg/ℓ or more. At this concentration chromium was found to accumulate in the rat's tissue; however, no changes in growth rate, food intake or blood analysis were noted.[17]

Other studies have shown that trace amounts of chromium in water supplies have no significant correlations with cancer.[1] It should be noted that these data are not conclusive.

Adult urinary loss of chromium is generally between 5 and 10 µg/day. This urinary loss corresponds to an intake of 20 to 500 µg/day.[33] The remainder either accumulates in the liver, spleen or bone marrow or is used in glucose metabolism or protein interactions.

The deficiency of chromium in man has been of more nutritional concern because it results in impaired glucose metabolism.[19] The impact of background concentrations of chromium has not been sufficiently studied, although excessive amounts (10 mg/kg body weight) are known to cause nausea, hemorrhage, circulatory collapse, and death. Based upon the available studies, chromium concentrations less than 5 mg/ℓ in water appear to have no measurable effect in the short run.

2.2.2 Aquatic Biota

The toxicity of chromium towards fish varies with species, chromium oxidation state, pH, and hardness. Individual studies have examined particular aspects of chromium toxicity, but no actual acute toxicity levels have been set. Table 2-1 summarizes one study of the experimental effects of chromium on warm water fish.[27]

From Table 2-1 and other studies,[9] a wide range of sensitivity to chromium among different species of organisms and in different waters is

Table 2-1

SUMMARY OF TOXIC LEVELS OF CHROMIUM TO FISH

Salt	Temp., °C	pH Before Salt	Dilution Water	Test Fish	96 hr. TL_m
Chromium Potassium Sulphate $CrK(SO_4)_2 \cdot 12H_2O$ (Trivalent Cr)	25°	7.5	Soft	Fatheads	5.07
		8.2	Hard	Fatheads	67.4
		7.5	Soft	Bluegills	7.46
		8.2	Hard	Bluegills	71.9
		7.5	Soft	Goldfish	4.1
		7.5	Soft	Guppies	3.33
Potassium Dichromate $K_2Cr_4O_7$ (Hexavalent Cr)	25°	7.5	Soft	Fatheads	17.6
		8.2	Hard	Fatheads	27.3
		7.5	Soft	Bluegills	118.0
		8.2	Hard	Bluegills	133.0
		7.5	Soft	Goldfish	37.5
		7.5	Soft	Guppies	30.0
Potassium Chromate $K_2Cr_3O_4$	25°	7.5	Soft	Fatheads	45.6

SOURCE: Pickering and Henderson.

apparent. The lethal levels reported vary from 17 to 118 mg/ℓ for fish; 0.05 mg/ℓ for invertebrates and 0.032 to 6.4 mg/ℓ for algae. The apparent "safe" concentration for fish is quite high; however, this concentration is lethal to other aquatic life. To protect all aquatic life the U.S. EPA has recommended maximum chromium concentrations of 0.05 mg/ℓ.[30]

The accumulation and elimination of hexavalent chromium (Cr^{+6}) by rainbow trout was studied by Knoll and Fromm. Test results indicated the main path of Cr^{+6} absorption was through the gills. Lower chromium levels in the blood in comparison to surrounding water suggested passive diffusion through the gills, and after exposure had stopped, the kidney and spleen were slow to lose chromium in comparison to other fish organs.[13]

Data regarding uptake and elimination of trivalent chromium (Cr^{+3}) by fish are available from only a few tests. When the fish are irritated by toxic levels of trivalent chromium they secrete large amounts of mucous, which complexes with the Cr^{+3} ion and reduces its diffusibility through the skin. The increased mucous secretion also tends to protect the gills of the fish.[4]

The accumulation of chromium in the bottom sediment has also been noted. Worms and clams living in the sediment develop chromium levels similar to those found in the sediment, while concentrations in the fish and water appear less. According to Mr. Richard Sparks of the Illinois Natural History Survey levels as high as 17 parts per million of chromium have been found in bottom sediment of the Illinois River. The biotic effects of these levels of chromium in sediment have not been documented.

2.2.3 Irrigation and Livestock

The U.S. Environmental Protection Agency in their Proposed Criteria for Water Quality established a maximum level of chromium in any water supply to be used for irrigation and/or livestock watering at 1.0 mg/ℓ. Specifically, the recommended maximum chromium concentration for continuous use on all soils is 0.1 mg/ℓ and for neutral and alkaline fine textured soils for a period of not more than 20 years it is 1.0 mg/ℓ.[29] These recommended limits are set because of the lack of knowledge concerning chromium accumulation and toxicity.

Even in its most soluble forms, chromium is not readily absorbed by animals. It is largely excreted in the feces.[19] The 1.0 mg/ℓ maximum of chromium is recommended to provide a suitable margin of safety.

The effects of chromium vary with plant species and chromium compound. The main toxic effects of chromium occur in the roots of plants. It was found that more than 0.1 mg/ℓ Cr^{+6} in a solution culture interfered with the uptake and translocation of essential elements by the roots of soybeans. Table 2-2 summarizes the observed effects of chromium on some different plant species,[22] and the data indicate chromium in either its hexavalent or trivalent forms is toxic for a number of plant species when concentrations are in the range of 1 to 5 mg/ℓ.

2.3 Current Status of Water Quality

Chromium is rarely found in natural waters, and a 1969 survey reported a mean chromium level of 0.0097 mg/ℓ for 1577 surface waters in the United States. Of these, 386 samples contained from 0.001 to 1.12 mg/ℓ chromium, and the remainder were less than 0.001 mg/ℓ. There are two

Table 2-2

EFFECTS OF Cr ON PLANTS

Plant Species	Cr Form	Cr Conc., mg/ℓ	Growing Medium	Observed Effects
Corn	Cr^{+3}	0.5	Solution culture	Stimulation of growth
Corn	Cr^{+3}	5	Solution culture	Moderate toxicity
Corn	Cr^{+3}	50	Solution culture	Severely stunted growth
L. Perenne	Cr^{+3}	10	Solution culture	Increased plant mortality
L. Perenne	Cr^{+6}	10	Solution culture	Increased plant mortality
Barley	Cr^{+6}	50	Soil	Severely stunted growth
Barley	Cr^{+6}	500	Soil	Death
Oats	Cr^{+6}	5	Sand	Iron chlorosis
Sugar Beet	Cr^{+6}	8	Sand	Iron chlorosis
Tobacco	Cr^{+6}	5	Sand	Retarded stem development
Corn	Cr^{+6}	10	Sand	Stunted growth
Sweet orange seedling	Cr^{+6}	75	Soil	No toxicity
Sweet orange seedling	Cr^{+6}	150	Soil	Observed toxicity
Soybean	Cr^{+6}	5	Loam soil	Inhibition of uptake of Ca, K, Mg, P, B, Cu

Source: National Research Council Canada, 1976.

water quality standards for concentrations of chromium which have been identified in Chapter 3, Water Pollution Regulations, and those levels are for general use and public water supply streams. For general use waters the acceptable hexavalent chromium concentration is 0.05 mg/ℓ while that for total chromium is 1.0 mg/ℓ. A more restrictive concentration of 0.05 mg/ℓ total chromium is required for drinking water supplies. The present water quality conditions are categorized according to these standards to depict the general acceptability of present water quality.

In Table 2-3 and Table 2-4 the violations of the general use and public water supply standards are itemized by river basin. According to Table 2-3, there are twelve of 576 water quality stations which violated the general use stream standard in 1976 and 1977. Nine of these water quality stations are located in the Chicago metropolitan area with the remaining three scattered over the Ohio, Wabash, and Big Muddy basins. The primary type of violation was the excursion of the hexavalent chromium level of 0.05 mg/ℓ. This excursion occurred in only 1% of the samples taken for the river basins in violation.

A more stringent criterion was the public water supply standard of 0.05 mg/ℓ total chromium. In Table 2-4 the number of water quality stations exceeding the public water supply criterion is much greater than that for general use. Seventy-three stations in ten river basins recorded excursions above the 0.05 mg/ℓ total chromium. These violations were distributed evenly in the Ohio, Wabash, Little Wabash, Des Plaines, and Big Muddy river basins with just a few in the other five basins.

Table 2-3

VIOLATIONS OF ILLINOIS GENERAL USE STANDARDS
OF 0.05 MG/ℓ HEXAVALENT AND 1.0 MG/ℓ
TOTAL CHROMIUM BY INDIVIDUAL RIVER BASINS

River Basin	Number of Water Quality Stations in Violation	% of Total Samples Taken in Violation	Maximum Cr Conc. Recorded (mg/ℓ)	
			Total Cr	Hexavalent Cr
Ohio	1	0.27	0.06	0.06
Wabash	1	0.68	0.46	0.18
Little Wabash	0	0	-	-
Upper Des Plaines	3	0.36	0.42	0.42
Lower Des Plaines	6	1.74	5.30	0.51
Big Muddy	1	0.36	0.40	0.37
Total	12			

Source: IEPA monitoring data 1976-1977

Table 2-4

VIOLATIONS OF ILLINOIS PUBLIC WATER SUPPLY STANDARD OF 0.05 MG/ℓ TOTAL CHROMIUM BY INDIVIDUAL RIVER BASINS

River Basin	Number of Water Quality Stations in Violation	% of Total Samples Taken in Violation	Maximum Cr Conc. Recorded (mg/ℓ)	
			Total Cr	Hexavalent Cr
Ohio	16	4.34	0.20	0.06
Wabash	11	3.73	0.46	0.18
Little Wabash	9	5.23	0.10	0
Illinois	2	0.32	0.08	0.02
Sangamon	2	0.87	0.09	0.02
Upper Des Plaines	7	1.25	0.42	0.42
Lower Des Plaines	10	2.91	5.30	0.51
Mississippi South	1	1.03	0.08	0
Mississippi South Central	4	2.84	0.07	0
Big Muddy	11	3.93	0.40	0.37
Total	73	2.3		

Source: IEPA monitoring data, 1976-1975

In only one case did the maximum chromium level appear extremely high and that was in the Des Plaines River basin, which is not a public water source. The actual percentage of samples exceeding the public water supply standard was only 2.3% of all samples taken. If not attributed to point sources (which appeared at only a small number of stations), then natural phenomenon, analytical error, or unregulated chromium dischargers could account for the excursions.

2.4 Anticipated Change in Discharger Status

Upon review of the IEPA and NPDES data, seven dischargers were identified who would be potentially impacted by the proposed chromium effluent standards. These dischargers represent an average hexavalent chromium loading of 15.5 pounds per day and a maximum hexavalent chromium loading of 78 pounds per day. The proposed regulation would reduce the quantity of chromium discharged by 56% to an average of 6.8 pounds per day and maximum of 13.7 pounds per day. The receiving streams benefitting from this reduction are the following:

Pecatonica River
Rock River
Nippersink Creek
Illinois River
Cone Creek
Aux Sable Creek
Big Creek

2.5 Anticipated Environmental Consequences

The expected change in chromium loading reaching Illinois streams is an average of 8.7 pounds per day, covering seven receiving streams. In Table 2-5, the maximum expected change in chromium concentration is

Table 2-5

CHANGES IN WATER QUALITY ASSOCIATED WITH PROPOSED REGULATION

Discharger	Average Change in Hexavalent Chromium (lbs/day)	7-day 10-year Low Flow of Receiving Stream (mgd)	Maximum Change in Stream Concentration of Hexavalent Chromium (mg/ℓ)[1]
A	0.021	0	0.23*
B	0.16	691	0.00003
C	No change	0	No change
D	0.01	1.3	0.0009
E	2.90	143	0.002
I	0.45	2093	0.00003
J	0.30	0	0.22*
K	4.80	1937	0.003

*For those streams where the low flow is zero, the change in stream concentration is the average change in effluent concentration.

[1]The change in stream concentration is based upon the following equation:

$$\Delta\text{Stream concentration} = \frac{\Delta\text{Average Cr Loading (lbs/day)}}{8.34 \times \text{Low stream flow (MGD)}}$$

tabulated for each stream. The greatest impact would occur upon the Big Creek, Aux Sable Creek, and Cone Creek because these streams have a seven-day, ten-year low flow of zero. The other receiving streams will also be incrementally upgraded by the proposed effluent regulation. Also, accumulation of chromium in the stream and river sediments will be reduced in a corresponding manner.

One additional environmental consequence which would result from the proposed regulation is the replacement of chromates in cooling systems with other corrosion-inhibiting formulations. Many of these formulations contain nutrients, such as phosphonates, and thus biocides may also be required to control biological growth. Such biocides may "add to the deterioration of the environment,"[16] and may be considered a detrimental consequence of the proposed regulation.

Chapter 3

BENEFITS OF A REGULATORY CHANGE

3.1 Introduction

For the proposed chromium regulatory change there is a resulting impact upon the water quality and the environment. Because lower levels of chromium will be discharged, there will be a beneficial change in water quality for water users and aquatic biota. In this chapter the specific receiving streams benefitting from the standard change will be examined and the benefits assessed accordingly.

3.2 Benefit Assessment

There are general and specific benefits associated with regulatory changes which enhance water quality. First, the streams specifically receiving the controlled pollutant will be upgraded, and, secondly, there is a general guarantee of future protection for all rivers and streams. In assessing the environmental advantages of the proposed regulation, special attention was given to those streams where water quality violations occurred and to those streams which received discharges containing chromium.

In Chapter 2 twelve water quality stations were identified which presently exceed the general use water quality chromium standard. Upon review of the impacted discharger locations there appears to be no correlation between the dischargers and the water quality of the affected twelve stations. Thus, there would be no change in the number of water quality violations recorded by the Illinois Environmental Protection Agency (IEPA).

The only specific benefits generated as a result of the proposed regulation will be assigned to users of the receiving streams associated with the seven impacted dischargers. Table 3-1 presents the change in chromium loading and its calculated impact upon stream chromium concentrations during low flow conditions. The proposed regulation provides significant changes in stream quality for two areas, and both are zero low flow streams. Based upon the results of Table 3-1, no changes in use benefits could be quantified with the other five receiving streams because of the nominal change in water quality. There is a qualitative concern with the accumulation of chromium in stream sediments and the ultimate fate of chromium in the environment. In the following section the specific benefits associated with adoption of the proposed regulation are described.

3.2.1 Impact of Chromium Upon Water Users

Chapter 2 depicted the general environmental consequences of high chromium concentrations in receiving streams. This information is used to describe the expected changes in water usage for the two receiving streams impacted by the proposed regulation. The following summary itemizes the benefits for each user group.

a. Public water supplies - The maximum hexavalent chromium concentration occurring in Aux Sable Creek and Cone Creek would exceed the public water supply standard of 0.05 mg/ℓ. These streams are intermittent by nature and not likely to be utilized as supplies; however, through the construction of a reservoir, Aux Sable Creek has been evaluated as a water supply source.[24] Thus, there may be future potential benefit in maintaining a high water quality in the Aux Sable Creek. It should be noted that in typical flow conditions the water quality concentration of chromium would be 0.0006 mg/ℓ on Aux Sable Creek.

Table 3-1

RECEIVING STREAM CHARACTERISTICS

Receiving Stream	7-day, 10-year Low Flow, mgd	Maximum Change in Hexavalent Chromium, mg/ℓ
Cone Creek	0	0.23
Rock River	691	0.0003
Big Creek	0	No change
Nippersink Creek	1.3	0.0009
Pecatonica River	143	0.002
Illinois River	2093	0.00003
Aux Sable Creek	0	0.22
Illinois River	1937	0.003

b. Farm water supplies - None of the streams affected by the proposed change exceeds the U.S. EPA recommended level for livestock water of 1.0 mg/ℓ total chromium during low flow conditions. Chromium is not readily absorbed by animals, and thus no immediate toxic effects would be anticipated from the maximum concentrations cited. During periods of average effluent quality, there would be no effects at all upon livestock. Thus, no benefits were assigned to the farm water uses.

c. Irrigation - Plants, such as soybeans, are affected by hexavalent chromium concentrations as low as 0.1 mg/ℓ.[29] Thus, the two receiving streams with maximum values greater than 0.1 mg/ℓ hexavalent chromium represent potential damage to crops irrigated with their water. Irrigation is not required in areas near these streams because of the rainfall characteristics in Illinois. Any excursions above the 0.1 mg/ℓ hexavalent chromium would not be for extended periods of time. Because of the small irrigation requirements and short duration of excursions, there are no agricultural benefits from the proposed regulation.

d. Aquatic biota - In assessing the impact upon stream life, there is concern for the effects of chromium upon invertebrates, algae, and fish. A chromium concentration of 1.0 mg/ℓ could be tolerated by fish but would be lethal to invertebrates and some algae. Of the seven receiving streams examined, only the two intermittent streams at low flow conditions exceeded the 0.05 mg/ℓ total chromium concentration recommended by the U.S. EPA.

In these two streams there would be an improvement in the stream ecology as a result of the proposed regulation. Chromium is a conservative pollutant, which may accumulate in the bottom sediments of a stream, and thus its effect upon worms, crustaceans, and mollusks is longer lasting than for fish and stream organisms. Also, a lower effluent standard would reduce the maximum discharge levels, and, therefore, offer greater protection to the aquatic biota. Thus, the aquatic food chain receives greater protection from accumulations of chromium. The chromium loading in bottom sediments would be reduced by 46% with the proposed regulation.

Other water user groups, such as navigation, industrial water supply, power generation, and recreation would be unaffected by the proposed rule change.

3.2.2 Benefit Estimation

The environmental benefits have been described for each user category, and now the benefits of public water supply, irrigation, farm water supplies, aquatic biota are qualitatively summarized for the affected streams. Table 3-2 presents the benefits anticipated from the proposed regulation.

Table 3-2

SUMMARY OF BENEFIT ASSESSMENT FOR PROPOSED REGULATION

BENEFIT CATEGORIES	LEVEL OF INFORMATION						
	QUALITATIVE BENEFIT ASSESSMENT	REFERENCE	QUANTITATIVE BENEFIT ASSESSMENT				
			Amount of Benefit	Units of Measure	Range of Benefit Uncertainty	$ Value	Range of $ Uncertainty
a. Public water supply	Only one stream, Aux Sable Creek, could be potentially a water source that is affected by a chromium discharge.		Potential future benefit				
b. Farm water supplies	Recommended level of 1.0 mg/ℓ not exceeded.						
c. Irrigation	Recommended level of 0.05 mg/ℓ chromium exceeded in two streams. Proposed standard would reduce the probability of excursion.		None			0	
d. Aquatic biota	Levels protecting algae, fish, invertebrates increased in two streams.						
	Reduced accumulation of chromium in bottom sediments of streams receiving chromium wastes. A reduction of 8.7 pounds per day hexavalent chromium in seven streams will decrease the probability of future damage due to sediment accumulation.						

Chapter 4

COSTS OF A CHROMIUM REGULATORY CHANGE

4.1 Impacted Population

The regulatory change proposed for the chromium effluent standards will require more stringent control by dischargers. This group will therefore pay greater costs for pollution control. These dischargers were identified upon the basis of IEPA and NPDES monitoring data for 1976, 1977, and 1978. By reviewing the performance of each plant and through questionnaires, the impacted dischargers were identified as three municipalities and eight industries.

Table 4-1 presents the number, type, and compliance characteristics of the eleven impacted dischargers. Of the eleven plants who would be potentially impacted by the proposed regulation, six exceed the present effluent limits for hexavalent chromium and one exceeds the trivalent chromium limit. The impacted dischargers are categorized as municipalities, electroplaters, and industrial firms using chromates in their cooling water system or in their process.

In all instances of present impact, it is the hexavalent chromium concentration which causes current compliance problems. Only one plant presently violates the trivalent standard, and this is believed to be the result of debugging a new chromium removal system. If the proposed total and hexavalent chromium standards are adopted, there will be ten

Table 4-1

COMPLIANCE STATUS OF IMPACTED DISCHARGERS

Discharger/ Type	Does Discharger Comply with Existing Regulations?		Does Discharger Comply with Proposed Regulations	
	Hexavalent Chromium[1]	Trivalent Chromium[2]	Hexavalent Chromium[3]	Total Chromium[4]
A/I	No	Yes	No	No
B/E	No	Yes	No	Yes
C/I	Yes	No*	Yes	No*
D/E	Yes	Yes		Yes
E/E	Yes (No)**	Yes (Yes)**	No (No)**	Yes (No)**
F/M	No	Yes	No	No
G/M	No	Yes	No	No
H/M	No	Yes	No	Yes
I/I	Yes	Yes	No	Yes
J/I	Yes	Yes	No	Yes
K/I	Yes	Yes	No	Yes

Key: M - municipality
E - Electroplater
I - Industry

[1]Present standard is 0.3 mg/ℓ daily maximum.

[2]Present standard is 1.0 mg/ℓ daily maximum.

[3]Proposed standard is 0.1 mg/ℓ monthly average, 0.2 mg/ℓ daily maximum

[4]Proposed standard is 1.0 mg/ℓ monthly average, 2.0 mg/ℓ daily maximum

*Temporary non-compliance

**Compliance based on IEPA monitoring data.

violators of hexavalent and four of these will also exceed the total chromium limitation because of the high hexavalent chromium concentrations.

To more specifically identify the nature of the compliance problem for these eleven dischargers, Table 4-2 was developed. The monthly average and maximum chromium concentrations are presented in Table 4-2 for all eleven dischargers. Seven of the dischargers have average hexavalent chromium concentrations of 0.25 mg/ℓ or less; however, the maximum levels reached as high as 5.4 mg/ℓ hexavalent chromium.

The variation between average and maximum monthly values is attributed to the source and present treatment methods utilized. Table 4-3 provides a summary of the discharger status in terms of sources and present treatment methods. All three electroplaters (B, D, and E) who have concentrated chromium wastes provide treatment facilities, and two of the three are considered in compliance with the existing regulations. Electroplater (B) did exceed the maximum hexavalent chromium in one instance but the consistency of performance warranted inclusion as in compliance.

The three municipalities (F, G, and H) receive industrial wastes which have caused each to repeatedly exceed the present standard, and in the case of one municipality, legal action is being sought against the industrial discharger. Local sewer ordinances are imposed to restrict chromium discharges.

Of the five industries impacted by the proposed regulation, three (A, I, and K) presently have no specific facilities for chromium removal. For industries A, I and K the chromium in their effluent is

Table 4-2

EFFLUENT CHARACTERISTICS OF IMPACTED DISCHARGERS[1]

Discharger	Type	Monthly Average Concentration, mg/ℓ		Daily Maximum Concentration, mg/ℓ	
		Hexavalent Chromium	Total Chromium[2]	Hexavalent Chromium	Total Chromium
A	Industry	0.23	0.24	3.8	3.8
B	Electroplater	0.22	0.39	1.3	1.4
C	Industry	0.05	-	0.2	22.0
D	Electroplater	0.06	0.07	0.24	0.42
E	Electroplater[4]	0.02 (1.04)	0.08 (1.04)	0.09 (10.7)	0.14 (10.7)
F	Municipality	0.32	0.41	1.2	1.2
G	Municipality	0.87	0.99	5.4	5.4
H	Municipality	0.9[3]	0.9[3]	1.8[3]	1.8[3]
I	Industry	0.2	-	0.3	less than 1.0
J	Industry	0.22	-	0.39	-
K	Industry	0.11	less than 1.0	0.72	less than 1.0

[1]Based on monthly NPDES reports and IEPA samples for 1976-1977.

[2]Total chromium based upon the addition of hexavalent and trivalent concentrations.

[3]Based on only two samples by IEPA.

[4]The values in parentheses represent IEPA data and values not enclosed are NPDES data.

Table 4-3

SUMMARY OF IMPACTED DISCHARGER CHARACTERISTICS

Discharger	Type	Chromium Source	Present Treatment	Does Discharger Presently Comply with Chromium Regulations?
A	Industry	Cooling water treatment	None	No
B	Electroplater	Plating baths and rinses	Continuous chromium removal facility	Yes
C	Industry	Plating baths and rinses	Chromium removal facility	No (temporary due to treatment plant debugging)
D	Electroplater	Plating baths and rinses	Chromium removal facility	Yes
E	Electroplater	Plating baths and rinses	Chromium removal facility	Yes (No)*
F	Municpality	Sewer discharger	Pretreat	No
G	Municipality	Sewer discharger	Pretreat	No
H	Municipality	Sewer discharger	Pretreat	No
I	Industry	Cooling water treatment	None	Yes
J	Industry	Process Water	Planned facilities	Yes
K	Industry	Cooling water treatment and plating wastes	None	Yes

*Compliance depends upon use of NPDES or (IEPA) data.

the result of utilizing chromates in their cooling water systems, while K, C, and J have plating facilities which use chromium. Depending upon the plant layout, water use, and other plant characteristics, the effluent quality changes for each discharger.

The variability in effluent quality is an important characteristic in assessing the compliance status and treatment requirements of impacted dischargers. The fluctuation between average and maximum hexavalent chromium concentrations ranges from 1.5 to 19. There are two levels of variability which occur, depending upon the use of chromium removal facilities. Figure 4-1 illustrates the distribution in effluent values for hexavalent chromium for a plant which does not have chromium removal facilities. There is considerable variation in the effluent quality, and maximum values are 5 to 7 times the monthly average. This distribution can be compared to that in Figure 4-2 for an electroplating facility with chromium treatment and removal facilities. Although there are values in excess of the proposed standard, the percentage (11 %) of high excursion is less than in Figure 4-1. With treatment the effluent quality appears to more consistently reach a specific chromium level as an average than the effluent from a plant without treatment. This variability in effluent quality is considered in assessing the compliance costs for the proposed regulation.

4.2 Chromium Treatment Technology and Compliance Costs

The proposed regulation will change the treatment requirements for eleven dischargers, and depending upon the use of chromium by the

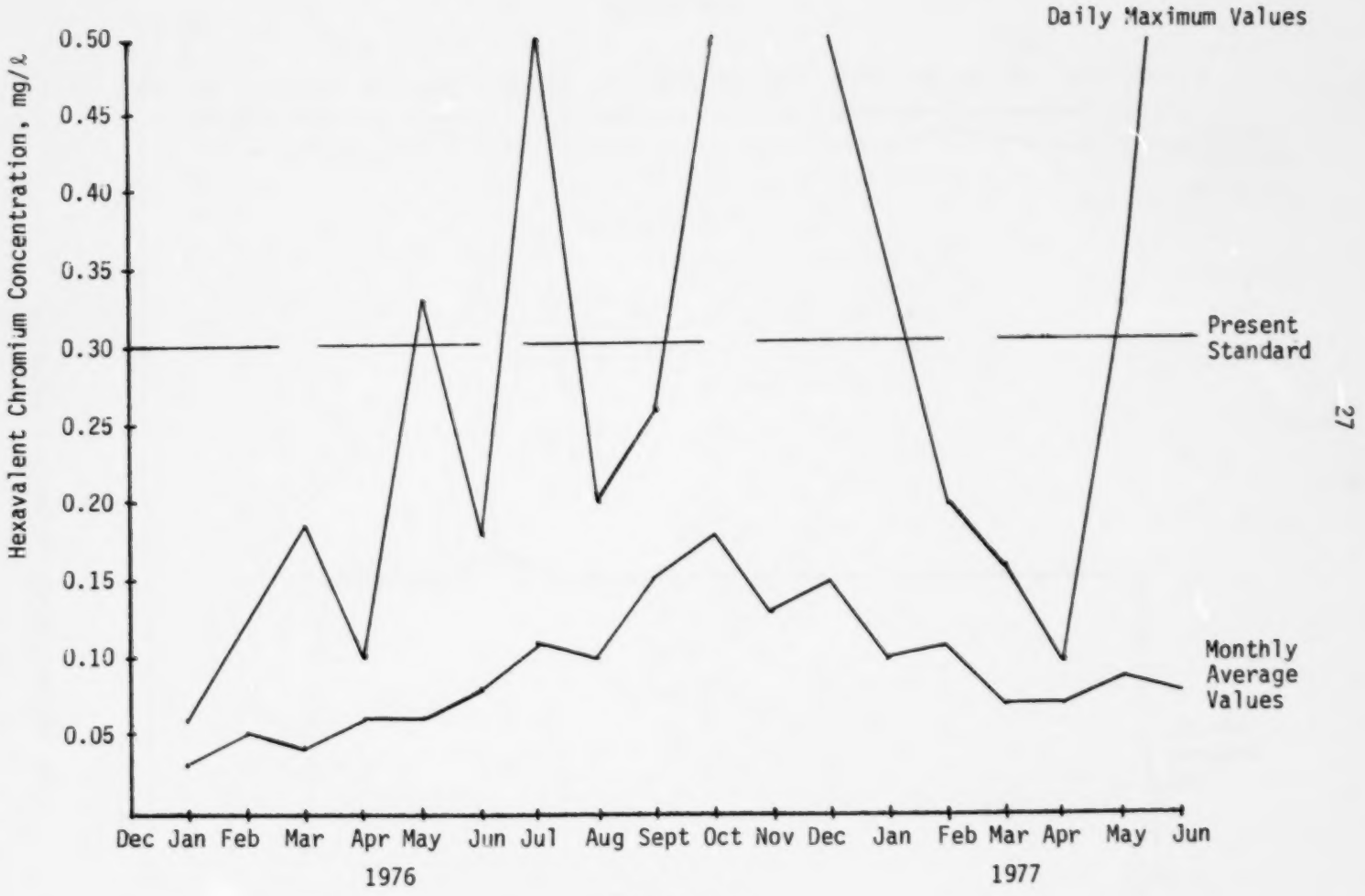

Figure 4-1

EFFLUENT QUALITY OF DISCHARGER WITHOUT CHROMIUM TREATMENT FACILITIES

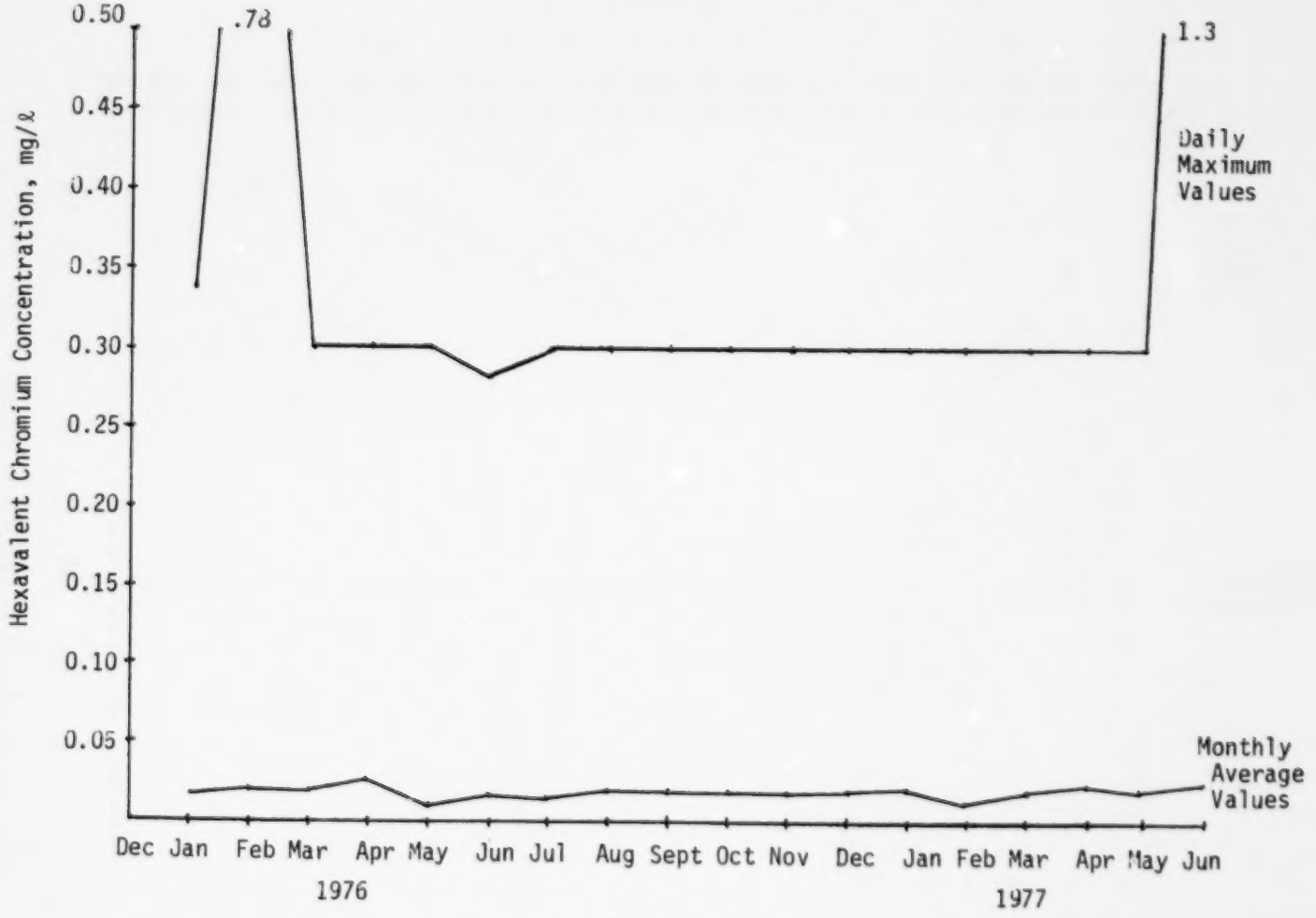

Figure 4-2

EFFLUENT QUALITY OF DISCHARGER WITH CHROMIUM TREATMENT FACILITIES

discharger. the treatment alternatives available will vary. For the municipalities, electroplaters, and industries identified in Table 4-1 and Table 4-2, alternatives for achieving compliance will be discussed in the following sections.

4.2.1 Municipalities

The three municipalities identified as exceeding the proposed standard receive chromium-bearing wastes from industries discharging to their sewers. These three municipalities exceed the present effluent regulations and by enforcing more stringent sewer ordinances, the muncipalities will be able to comply with the present and proposed regulation.

Compliance costs to achieve the existing sewer standard will not be attributed to the proposed regulation, especially since there is non-compliance with the existing standard. The promulgation of federal pretreatment standards will also insure more uniform sewer effluent quality at costs not associated with the proposed regulation.

4.2.2 Electroplating and Metal Finishing

Chromium is utilized in several different metal finishing and metal processing operations and thus appears in the effluent of many electroplaters and metal finishers. The following list of processes indicates the widespread use of chromium in the chemical baths for various metal finishing operations:[28]

- Plating and electroplating
- Etching
- Anodizing
- Electropolishing
- Metal spraying
- Dying and painting

Process baths and/or rinsing operations in each of the above categories may contain chromic acid (CrO_3). The concentration and quantity of chromium utilized depends, of course, upon specific plant use. In the appendix the electroplating process and pollution sources are discussed in detail. The treatment methods utilized by electroplaters can also be used by other dischargers, and thus a general description of techniques and expected effluent quality is presented in the following section.

4.2.2.1 Treatment Methods

There are two general ways of improving the quality of plating wastes; either modifying the area of the operation causing the waste problem or installing chemical treatment to destroy or remove the waste problem. The usual treatment methods for the removal of chromium in wastewater are chemical or physical, and there are three common techniques which are described below.

A. Reduction and Precipitation

The most widely used treatment method consists of lowering the pH of the waste streams to 3.0 or below followed by a chemical reducing step. The chemical reducing step converts Cr (VI) to Cr (III) by the addition of SO_2, $FeSO_4$, or metabisulfite. When the reduction is complete, an alkali is added to neutralize the acid and precipitate CR (III). The chemistry of this method using ferrous sulfate is shown in the following reactions:[23]

$$H_2CrO_7 + 6FeSO_4 + 6H_2SO_4 \rightarrow Cr_2(SO_4)_3 + 2Fe_2(SO_4)_3 + 7H_2O$$

$$Cr_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 2Cr(OH)_2 + 3CaSO_4$$

$$Fe_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 2Fe(OH)_3 + 3CaSO_4$$

This removal procedure may occur in a batch or continuous process. The batch technique is very simple, but requires substantial labor, large paired tanks, and is subject to chemical overdosing. An operator is needed to add chemical to a full tank, after which settling occurs. The clean top water is then drained and the remaining sludge is disposed of in a suitable disposal area.

For the greatest control, least labor and chemical costs, and widest range of applicability, continuous chromium treatment is now being used. Such a system requires instrumentation for measuring and controlling the treatment processes as well as settling facilities and/or filtering equipment.

B. Ion Exchange

This method produces a reusable water which may be advantageous in some areas where water costs are high. Anion exchange removes chromates and dichromates while cation exchange removes trivalent chromium. In the ion exchange system, (if removal is to be accomplished)[26] pH is the critical factor to be controlled.

C. Evaporative Recovery

This process consists of evaporating the waste rinse water leaving chromic acid behind for recovery and reuse. The major disadvantage of this process is that not only the chromic acid is left behind, but also all the other constituents of the wastewater.[6]

The type of effluent quality achieved from the use of these three treatment methods has been documented by Patterson[26] and general examples

cited are listed below:

Wastewater Treatment	Achievable Hexavalent Chromium Concentration, mg/ℓ
Reduction of plating waste	1.0
Continuous treatment of plating waste	0.05
Reduction of dilute waste	0.10
Reduction of plating waste	0.7-1.0
Two-stage reduction of plating rinse water	>0.1
Reduction of plating waste	≥0.1
Reduction of plating waste	0.001 to 0.4
Reduction of steel mill waste	0.01
Ion exchange of plating waste	0.023
Ion exchange of plating waste	0.025
Ion exchange of cooling tower blowdown	0.0 to 0.9

These examples represent typical values obtained from treatment systems; however, there is no discussion of effluent variability with respect to monthly average or maximum values.

4.2.2.2 Present Discharge Levels

Three electroplating dischargers (B, D, and E) were identified as being impacted by the proposed regulation because of their present effluent quality. Although all three have chromium treatment systems, the variation in average and maximum concentrations would exceed the proposed regulation, and, indeed, one discharger exceeds the present

effluent regulation. According to Table 4-2, the average hexavalent chromium concentration is 0.22 mg/ℓ, 0.06 mg/ℓ, and 0.02 (1.04) mg/ℓ* for the three platers. Thus, only one of the three can achieve the proposed monthly average. Maximum hexavalent chromium concentrations, of all three, however, exceed the proposed limitation.

To place the treatment performance of these plants in perspective, one can examine the national average performance. The number of electroplating firms in the United States is estimated to be about 9400. Of these, 6600 are estimated to discharge approximately one billion gallons a day of metal finishing process water into publicly owned treatment facilities.

Seventy-three plants sampled by the EPA had chrome reduction facilities. Approximately 60% of these plants already meet the proposed specified limitations shown below for pretreatment by the use of sulfur dioxide at low pH.[10]

	Pretreatment Standard	
Chromium type	Maximum any one day	Average for 30 consecutive days
Cr (VI)	0.25 mg/ℓ	0.09 mg/ℓ
Cr (total)	4.2 mg/ℓ	1.6 mg/ℓ

A range of compliance costs is possible for the affected electroplaters. Minimum costs incurred by these three dischargers will consist of additional chemical and maintenance costs to improve the performance of their existing facilities. If such actions are not sufficient to establish compliance, then additional capital expenditures for treatment plan expansion would be required.

*Electroplater E was assumed out-of-compliance based on the IEPA monitoring data.

4.2.3 Industrial Users of Chromium

There were two uses of chromium within the five industries identified. The cooling water application has been segregated from the process utilization since each use involves different treatment alternatives and costs. The three industries utilizing chromium in their processes are described in this section.

Firms engaged in metal fabrication or processing may utilize chromic acid in plating, etching, anodizing, electropolishing, metal spraying, or painting. Treatment of such waste streams depend upon plant age, plant layout, and the concentration and volume of the chromium-bearing waste stream. The sources of chromium waste and treatment methods for these industrial users are similar to those described in the electroplating industry.

Two (J and K) of the three industries impacted by the proposed regulation presently comply with the effluent standard, and the third, Industry C, will comply upon debugging of its treatment system. Discharger C and J have equipment for chromium removal but only Discharger C can comply with the proposed regulation without any additional cost. Implementation of the proposed standard will cause Discharger J and K to violate the average monthly and maximum Cr (VI) levels. Thus, noncompliance with the proposed hexavalent chromium limitations will result in capital expenditures for Discharger K, and in operating cost increases for Industry J. In Section 4.3 the compliance costs associated with the proposed regulation are estimated for these impacted dischargers.

4.2.4 Users of Chromates in Cooling Towers

Because chromate salts have traditionally been the most effective corrosion inhibitors available, these salts have been used in cooling systems. While chromate levels from 200 to 500 mg/ℓ provide outstanding corrosion protection, economic and environmental constraints generally limit this form of treatment to closed systems. The most common type of chromate treatment used today is the zinc dianodic, which maintains the following concentrations in the circulating waters:

Chromate, $CrO_4^{=}$ = 15-25 mg/ℓ (7 to 12 mg/ℓ as Cr^{+6})

Zinc = 2-5 mg/ℓ

Total phosphate = 2-5 mg/ℓ

Where environmental constraints have limited the above type of cooling water treatment (because of hexavalent chromium in the discharge), alternative corrosion inhibitions have been sought. A low level chromate treatment (5 to 10 mg/ℓ chromate) has been successfully used, although it is more sensitive to other parameters such as pH, hardness, process leaks into the cooling water, and so forth. Where even the low chromate treatment is unacceptable because of discharge limitations on chromium, non-chromium treatment has been used. Poly phosphates are the most popular non-chrome treatment, and are often used in conjunction with phosphonates and zinc. Non-chromate treatment systems are not as effective as chromate treatment and thus their use will result in higher corrosion rates. Non-chromate treatment also requires closer operating control than chromate treatment in order to do an effective job, and additional biocides are generally required.

There are several penalties associated with switching to a non-chromate treatment, including:

- Higher operating labor costs
- Higher chemical costs
- Higher biocide dosages required
- Higher maintenance costs due to higher corrosion rates
- Shorter equipment life because of the higher corrosion rates.

The proposed regulation is of primary concern to those chromate users who meet the existing effluent limitations but currently do not meet the proposed standards. Dischargers A and I will be required to either switch corrosion inhibitors or to install a chromium removal system. Also, Discharger K, who also utilizes chromium in plating applications, maintains a chromate concentration in the cooling tower, and may have to modify its corrosion prevention program. The potentially impacted chromate users provided some cost data on the impact of the proposed modification. The tradeoffs with choosing another corrosion inhibitor program for one of the impacted users, are itemized in Table 4-4. As chromate treatment is reduced, operating costs of the cooling system increase. These direct costs plus lower protection for the system are the result of lower chromate usage. If the chromate concentration is maintained and treatment of blowdown is advocated, then an ion-exchange or other removal system for chromium may be used.

Discharger I maintained that because of the proposed regulation, chromium treatment facilities would be installed at a capital cost in excess of $1 million, instead of switching to an alternative corrosion

Table 4-4

COSTS FOR REDUCED CHROMATE USAGE IN WATER TREATMENT APPLICATIONS

Present Hexavalent Chromium Effluent Level	Treatment Program	Associated Problems	Associated Total Annual Costs
Present practice	Chromate 5-10 ppm (with 15 ppm zinc) Deposit Inhibitor	a. Corrosion rate <2.0 mils/hr b. Require tighter control c. Corrosion rate	$2,300 for chemicals plus 1 operator
Reduce chromates by 50%	Chromate 2-5 ppm (with 10 ppm zinc) Deposit Inhibitor plus	a. Corrosion rate <3.0 mils/yr b. Tight control required c. More test procedures d. Increasing biological problems	$26,000 for chemicals and 1.5 operators
Eliminate chromates	Phosphonates 50 ppm (with 10 ppm zinc) Specific corrosion inhibitors	a. Corrosion rate <5.0 mils/yr b. Good control requires more man-hours c. Biological problems can be severe	$36,000 for chemicals plus 2.0 operators

Source: Discharger K

inhibitor. This provides some indication of the value placed on chromate cooling water treatment over the available alternative chemicals marketed.

4.3 Costs of Compliance

There are three different costs associated with attaining compliance for the proposed regulation. The installation of additional treatment facilities would be required for two (D and K) of the seven dischargers. For three dischargers (B, E, and J) adoption of the proposed regulation would increase the operating costs of their present treatment system. And, two dischargers (A, and I) would be compelled to eliminate the usage of chromates in their water treatment system or install treatment systems. No costs were assessed to the three municipalities or the one industrial discharger with a new treatment system on-line.

In Tables 4-5 and 4-6 the expected incremental capital costs and operating costs, respectively, are summarized for seven dischargers who must modify their present mode of operation. The method for deriving these specific cost estimations is contained in the Appendix, and these estimations were based upon communication with each discharger regarding their compliance alternatives and the cost data from Patterson's Technology and Economics of Industrial Pollution Abatement.

According to Table 4-5 there are only three dischargers, D, I, and K, who incur capital expenses if the proposed regulation is adopted: however, these costs are $5,400,000. If the alternative regulation of 0.15 mg/ℓ average and 0.3 mg/ℓ maximum hexavalent chromium is adopted,

Table 4-5

INCREMENTAL OPERATING COSTS WITH ALTERNATIVE EFFLUENT REGULATIONS

Discharger	Increased Annual Operating Costs, for Alternative of 0.15/0.30 mg/ℓ Chromium Hexavalent**	Increased Annual Operating Costs, for Proposed of 0.10/0.20 mg/ℓ Chromium Hexavalent**	Source of Cost
A	4,500	4,500	Increased chemical usage
B	1,300	1,300	Increased chemical usage and maintenance
C	0	-	-
D	0	900	Increased chemical usage and maintenance
E	3,200	3,200	Increased chemical usage and maintenance
I	160,000	160,000	Chromate treatment
J	1,300	1,300	Increased chemical usage
K	0	4,300,000	Chromates eliminated in cooling system Plating treatment
Total	170,300	4,500,000	

*F, G, and H are municipalities and no costs of compliance were assigned (See discussion in Section 4.2.1).

**Includes annualized capital investment where such expenditure was required.

Table 4-6

INCREMENTAL CAPITAL COSTS WITH ALTERNATIVE EFFLUENT REGULATIONS

Discharger	Capital Cost for Alternative Regulation (0.15/0.3) mg/ℓ hex.-chromium. $	Capital Cost, for Proposed Regulation (0.1/0.2) mg/ℓ hex-chromium, $	Source
A	0	0	-
B	0	0	-
C	0	0	-
D	0	$5000-$10,000	-
E	0	0	-
I	1,000,000	1,000,000	Chromate removal system for blowdown
J	0	0*	-
K	0	4,400,000	Treatment of 4 mgd stream using ion exchange
Total	1,000,000	5,400,000	

*Treatment facilities are under consideration.

F, G, and H are municipalities and no costs of compliance were assigned. (See discussion in Section 4.2.1).

these capital costs decrease to $1,000,000. The incremental increase in operating costs is $4,500,000 per year with the proposed regulation or $166,000 for the alternative regulation.

4.4 Economic Impact

The compliance costs incurred by the seven impacted dischargers result in increased operating expenses for these plants. The economic adjustment resulting from such costs varies according to the magnitude of the cost and the economic condition of the plant. For five (A, B, D, E, and J) of the seven dischargers the increased operating costs would not likely affect the economic condition of the plant. Only dischargers D, I and K would be required to invest capital in chromium control equipment. Such expenditures would not cause plant closure but may curtail future expansion plans and could affect the plant profitability.

No changes in industrial output or prices, commercial output or price, and agricultural output or prices is anticipated. Local services and taxes will remain unchanged.

Chapter 5

COSTS AND BENEFITS OF REGULATION

The costs and benefits of the proposed regulation have been considered separately, and yet it is important to assess the relative magnitudes of each. In this chapter the total social costs and benefits obtained are formally presented and discussed. The limitations to the analysis are clearly delineated since these items affect the magnitude of the impact and the final assessment of the feasibility of the proposed regulatory change.

5.1 Analysis of Total Social Costs and Benefits

In Chapters 2 and 3 the expected environmental consequences of the proposed rule change were found to be improvements in water quality for seven receiving streams through the reduction of 8.7 pounds per day of hexavalent chromium. This reduction in chromium loading was balanced against the costs imposed upon seven dischargers.

Table 5-1 summarizes the expected costs and benefits for the proposed regulatory modification and an alternative effluent regulation. The important consideration of the proposed regulatory change is the impact on two small receiving streams versus the increased cost of operation for seven industrial dischargers. Two levels of effluent regulations were reviewed to indicate the possible reduction in compliance costs which may result in the same environmental benefits. It is possible to consider an alternative effluent standard of 0.15 mg/ℓ hexavalent chromium as a monthly average and 0.30 mg/ℓ hexavalent chromium

Table 5-1

TOTAL SOCIAL BENEFITS AND COSTS

Regulatory Scenario	Total Social Costs	Total Social Benefits
I. Existing effluent standard	Existing costs	Existing water quality
II. Proposed regulation, R76-21 0.1 mg/ℓ, monthly average Cr^{+6} 0.2 mg/ℓ, daily maximum Cr^{+6} 1.0 mg/ℓ, monthly average Cr (total) 2.0 mg/ℓ, daily maximum Cr (total)	A. Additional operating costs of $4,500,000 per year.[1] B. Capital expenditures of $5,400,000 C. Increased discharge to two streams of biocides and nutrients replacing chromates in cooling system.	A. Protection of Aux Sable Creek as future water supply source.[24] B. Greater protection of aquatic biota in Aux Sable Creek and Cone Creek, especially invertebrates and algae. C. Reduced accumulation of chromium by 56% over existing conditions. D. Hexavalent chromium loading reduced by 8.7 pounds per day.
III. Alternate regulation 0.15 mg/ℓ, monthly average Cr^{+6} 0.30 mg/ℓ, daily maximum Cr^{+6} 1.0 mg/ℓ, monthly average Cr (total) 2.0 mg/ℓ, daily maximum Cr (total)	A. Additional operating costs of $170,000[1] B. Capital expenditure of $1,000,000 C. Increased discharge to one stream of biocides and nutrients replacing chromates in cooling systems.	A. Protection of Aux Sable Creek as future water supply. B. Greater protection of aquatic biota in Aux Sable Creek and Cone Creek, especially invertebrates and algae. C. Chromium accumulation in sediment reduced by 34% over existing conditions. D. Hexavalent chromium loading reduced by 5.3 pounds per day.

[1]Includes annualized capital costs.

as a daily maximum which reduces the incurred costs with an incremental environmental change. With the alternative effluent regulation there would be a 5.3 pound per day decrease in hexavalent chromium rather than the 8.7 pounds per day reduction associated with the proposed regulation. This incremental change of 3.4 pounds per day or 1240pounds per year would reduce capital investment by a maximum of $4,400,000 and operating expenses by $4,330,000.

The accumulation of chromium in the bottom sediment of streams would be reduced by 56% or 34% over existing conditions, for the proposed and alternative regulation, respectively. Thus, both regulations offer an improvement in water quality or, at least, greater protection of the environment; however, the incurred costs for the two levels of regulation do vary substantially.

The expected environmental benefits are site specific because of the limited number of affected dischargers. Thus, the costs incurred must be balanced against the significance of streams, such as Aux Sable Creek and Cone Creek and the accumulative effect of chromium in stream sediment. There is an important consideration in evaluating these water quality impacts, and that is the enforcement of the general use water quality standard to protect these smaller streams. The use of this water quality standard insures the protection of such small streams, regardless of the effluent standard selected.

It, thus, appears that the important issue becomes one of adopting a standard that limits the usage of chromium or at least insures treatment by all "large" dischargers of chromium. Such a usage limitation

may be desirable if there is concern over future water quality and accumulative effects of chromium in stream sediments.

5.2 Sensitivity Analysis

There are uncertainties in the estimation of costs and benefits associated with the proposed regulatory change. These uncertainties act as limitations to the accuracy of the economic analysis. For each of the following constraints there is a brief description of its impact upon the study results.

5.2.1 Compliance Cost Estimates

There is some uncertainty in determining specific cost estimates for impacted plants. Although companies were contacted to obtain specific data, a variety of compliance alternatives resulted in a range of possible costs. The two greatest capital and operating costs were incurred by Dischargers I and K. Several alternative actions for achieving compliance were available to each discharger. For Discharger K rearrangement of waste streams or treatment of the entire effluent are expensive alternatives. Even though removal of chromates in cooling tower application may have alleviated some of the compliance problem, the company would choose to make in-plant changes first. The probability of incurring a maximum cost of treatment of a 4 mgd waste stream is low but provides an estimate of costs incurrred. Discharger I chose treatment of cnromates in a cooling tower blowdown rather than eliminate their use. Such a choice results in a large capital investment and operating cost. Although this is not the most inexpensive method for solving

an effluent compliance problem, it is the only choice if the discharger decides that elimination of chromates is not feasible. Thus, such situations alter the apparent costs of compliance for impacted dischargers.

5.2.2 Constraints to Benefit Estimation

In assessing the benefits of the proposed change, there must be a clear understanding of the fate of chromium in the environment. However, there are uncertainties as to the long range effects of chromium in the human body and in the aquatic environs. Research has been limited which explores cumulative effects of low levels of chromium in drinking water and in streams. Although the water quality standards and recommended concentrations of chromium in waters for irrigation, livestock, and ingestion appear to be adequate, based upon Chapter 2 discussion, the paucity of data must be acknowledged.

In addition to the lack of knowledge regarding long term chromium effects, there must be some mention of the concern for future water quality protection. Twelve water quality stations did exceed the general use stream standard for chromium, and consideration of the impact of future industrial dischargers is also an unquantified factor in the analysis.

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Appendix to Chapter 4

A. Description of Chromium Usage in Electroplating

Chromium Plating

Chromium is utilized in electroplating operations to provide the plated material with (1) corrosion protection, (2) wear resistance, and/or (3) decorative appearance.

There exist two general types of chromium plating, decorative and hard. Decorative chromium plating is generally applied over undercoats of nickel or copper to a thickness of not more than 0.1 mil for the purpose of enhancing appearances. Hard chromium plating, on the other hand, is primarily applied to increase corrosion and wear resistance at a coating thickness of 0.1 to 20 mils or more.[20]

Chromium can be plated onto the surfaces of such metals as zinc, steel, aluminum, copper, brass, nickel, silver, magnesium, cadmium and even plastics. Table 4-4 gives a general idea of the most commonly used materials for chromium plating.[31]

Sources of Chromium Wastes

The electroplating procedure includes cleaning, electroplating, rinsing, and drying of the material to be plated. Table 4-5 illustrates the process flow of chromium plating on specific materials.[28] Once the material has received a chrome layer, there is a rinsing operation with water and then oven drying.

Wastes in the form of hexavalent and trivalent chromium come almost

Table A-1

MAKEUP OF TOTAL CHROMIUM PLATING BY MATERIALS

Material	Percent of Total Chromium Plating
Steel	54.0
Zinc die cast	33.9
Brass	4.0
Aluminum	0.1
Plastics	2.0

Scurce: U.S. Environmental Protection Agency, Development Document for Effluent Guidelines of the Electroplating Industry

Table A-2

FLOW CHART OF CHROMIUM PLATING ON SOME COMMON METALS

Copper	Aluminum	Stainless Steel	Nickel-Silver
Cathodic clean	Etch Clean	Cathodic clean	Cathodic clean
Water rinse →	Water rinse →	Water rinse →	Water rinse →
Hydrochloric acid dip	Nitric acid dip	Treat as anode in chrome plating solution	Hydrochloric acid dip
Water rinse →	Water rinse →		Water rinse →
Chrome solution	Chrome solution	Chrome solution	Chrome solution
Water rinse →	Water rinse →	Water rinse →	Water rinse →
Drying oven	Drying oven	Drying oven	Drying oven

Source: Nemerow, Liquid Waste of Industry

exclusively from the accidental discharges of the processing baths and rinse waters. Several sources of accidental discharges are possible, such as the following:[11]

1. process tank overflows
2. tank leakage
3. pump, hose, or pipe rupture
4. drippage of workpieces during transfer between tanks
5. spills.

In the rinsing operation, which is very important in obtaining good quality control, the concentration of Cr (VI) in the rinse water averages about 50 mg/ℓ to a maximum of 600 mg/ℓ.[28] The rinse waters, which account for 90% of all chromium waste, vary in volume and concentration for each installation. The levels of chromium in the untreated wastewater of a typical electroplating facility are shown below.[31]

Chromium Type	Estimated Untreated Wastewater Conc.
Cr (III)	0.05 mg/ℓ
Cr (VI)	17 mg/ℓ
Cr (total)	17 mg/ℓ

Because of the chromium concentration in the untreated wastewater, many electroplaters provide treatment of this waste prior to discharge into streams or municipal sewer systems.

APPENDIX TO CHAPTER 4

B. COST ESTIMATION FOR DISCHARGER COMPLIANCE

Costs will be incurred by electroplaters and other industrial dischargers using chromates in process or in cooling water systems. The costs estimations for each group are described herein.

I. Compliance Costs for Users of Chromates in Cooling Systems

Two operating cost increases are associated with replacement or treatment of chromates. For Dischargers A, I, and K chromates are used in cooling water systems. The costs for A and I are described herein and the cost for K are discussed separately in Section IV.

Discharger A in eliminating chromates will increase chemical usage and labor requirements. Utilizing the cost data provided by Discharger K, a proportion of the chemical costs was allocated to A's process according to the flow rate.

Discharger K's costs were $33,000 per year for 85 mgd recirculating capacity. This translates into a cooling tower blowdown rate of approximately 300,000 gpd. Then, for Discharger A, who has a blowdown of 40,000 gpd:

$$\text{Annual chemical cost for discharger} = \$3300/\text{yr} \frac{40{,}000 \text{ gpd}}{300{,}000 \text{ gpd}}$$

$$= \$4{,}500/\text{yr}$$

Discharger I stated that chromium removal facilities would have a capital cost greater than $1,000,000. Discharger I averages 0.2 mg/ℓ hexavalent chromium in their effluent, and approximately 0.5 mgd. This translates into about 1 pound per day of hex chrome. Assuming a 50%

reduction across their existing facilities, this translates into a blowdown of 2 pounds per day of Cr^{+6}, or 4 pounds per day as $CrO_4^{=}$. Assuming an ion-exchange system is installed, a treatment cost of $1.00 per pound of CrO_4, the annual operating cost would be negligible compared to the annualized capital cost of $160,000 (based on the company's $1,000,000 capital estimate). Thus, the $160,000 figure will be used as the net operating costs.

II. Compliance Costs for Electroplaters B, D, and E

The compliance costs for the electroplaters consist of increased chemical costs were based on cost curves from Patterson's Technology and Economics of Industrial Pollution Abatement, an index for updating values to 1977, and the assumption that a maximum increase of 40% in dosage and maintenance costs would bring compliance for the three electroplating firms. The actual estimates are shown below:

Discharger B = Costs based on 0.164 mgd flow, Figure 2, p. 83

$150/month x 12 months/yr x 1.83* x 0.4 = $1300

Discharger D = Costs based on 0.3 mgd flow, Figure 2, p. 83

$360/month x 12 months/yr x 1.83* x 0.4 = $3200

Discharger E = Costs based on 0.025 mgd flow, Figure 2, p. 83

$100/month x 12 months/yr x 1.83* x 0.4 = $900

In conversation with Discharger E, capital costs of $5000 to $10,000 would be incurred for additional holding tanks and additional auxiliary equipment.

*1.83 is the M&S index of 1977/1978 values to update Figure 2 costs to 1977.

III. Compliance Costs of Discharger J

Discharger J presently uses chromium in a process application and provides a sodium bisulfite treatment for control of hexavalent chromium. There is now under consideration installation of an electrolytic removal system as part of a $200,000 project to upgrade treatment facilities for suspended solids removal. For the purposes of this study, only increased chemical costs will be assessed as a minimum cost. These costs are based on Figure 2 of Patterson's Technology and Economics of Industrial Pollution Abatement and an index of 1.83 for updating the costs.

Discharger J = $150/month x 12 months/yr x 1.83 x 0.5

= $1300/year in costs

IV. Compliance Costs of Discharger K

Discharger K faces a difficult treatment situation in that each of the following alternative's available is expensive and/or difficult to implement:

1. Treatment of 50% of the 8 mgd stream from 0.3 mg/ℓ chromium maximum to 0.1 mg/ℓ as a daily maximum using ion exchange.

2. Treat 20 sources of chromium inplant by segregation of sewers and construction of separate facility or elimination

3. Eliminate chromates in cooling tower application and in some processing applications to achieve standard

Costs for alternatives 1 and 3 are provided herein.

A. Assuming sodium bisulfite system for 4 mgd would gain compliance, costs are based on Patterson's costs for 1 mgd plant as shown below (ref. 25, p. 97)

Operating cost = $0.78/1000 gal (1972)

Capital cost = $0.81/1000 gal (1972)

Costs for discharger K are as follows:

Operating cost = $\left(\frac{4}{I}\right)^{0.67}$ x \$0.78/1000 gal x 1.46* = \$2.92/1000 gal

Capital cost = $\left(\frac{4}{I}\right)^{0.67}$ x \$0.81/1000 gal x 1.46* = \$3.03/1000 gal

*1.46 is factor for updating costs to 1977.

Annual operating cost = \$2.92/1000 gal x 4 mgd x 365 days = \$4,300,000

Capital cost = \$3.03/1000 gal x 4 mgd x 365 days = \$4,400,000

B. Costs for eliminating chromium in cooling tower application:

\$13,000 - chemical cost increase
\$20,000 - labor cost increase
\$33,000 operating cost increase

Elimination of chromates in the cooling tower would be a measure of last resort, and as such is an additive cost to the treatment of plating waste streams.